American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)
ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Methods of Reasoning in Scientific Discovery

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Abstract

In this paper, we briefly discuss the forms of arguments and the methods of reasoning in scientific experiments, namely, inductive reasoning, abductive reasoning and deductive reasoning. We find that generalization is in human nature, and it is only a conception without any perception. The short comings of the applications of deductive reasoning and inductive reasoning are analyzed using examples. It is observed that deductive reasoning and inductive reasoning methods are invalid in scientific reasoning. We discuss the vulnerability of the foundation of science that is based on the methods of inductive reasoning and deductive reasoning. We find that it is by abductive reasoning that theories are constructed to explain empirical observations. Abductive reasoning is only the reasoning method that can be applied for the observations in the empirical world. Finally, we conclude that the best and the most effective method of reasoning is the abductive reasoning for scientific experiments.

Keywords: General Statement; Statistical generalization; Inductive Generalization; Induction; Deduction and Abduction.

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1. Introduction

From the ancient times, people have been performing experiments to study the behavior of nature. We think that finding the behavior of physical and biological phenomena is a part of human nature. Based on experiments and observations, to understand nature and constructing theories is very important. According to the literature, it is generally accepted that there are two methods of reasoning, namely, deductive reasoning and inductive reasoning. Francis Bacon has been called the father of empiricism [1]. His works argued for the possibility of scientific knowledge based only upon inductive reasoning and careful observation of events in nature [1]. We think that Galileo Galilee can be considered as the father of the method of deductive reasoning. A school of philosophy, called, empiricism uses inductive reasoning to discover scientific knowledge. According to empiricism, the sense experience is primary and mental faculty is secondary in gaining knowledge. Deductive reasoning method is used by the school of philosophy called rationalism. They say that mental faculty is primary and sense experience is secondary in producing knowledge. Based on a finite number of observations to obtain a generalized abstract statement is the main purpose of the method of induction whereas to arrive at a conclusion from a generalized statement is the general idea of the method of deduction. Therefore, in the past, most researchers have been using the reasoning methods induction and deduction to arrive at conclusions from their experiments. Even though they use these methods, we observe that basic requirements are not satisfied in the applications of these methods. In 1866, philosopher, logician, mathematician and scientist, Charles Sanders Peirce [2] introduced another method of reasoning, called; abductive reasoning that is more effective for every experiment than inductive reasoning and deductive reasoning. In abductive reasoning, considering the whole set of observations of the experiment, the researcher formulates a statement as the best explanation of the observations. In this paper, we confine ourselves to a discussion only of concepts, weaknesses, comparisons and reasoning methods, involving scientific experiments and human nature, and their generalizations. Thus, our study is restricted to such fields.

2. Preliminary concepts

The following definitions of concepts are from various authors as stated in the literature.

2.1 Empirical world

The world that we conceive and perceive is defined as the empirical world [3].

2.2 Predicate

A predicate is the property or attribute or mode of existence of the subject [4]. A given subject possesses or does not possess a given predicate. The color (property) of a table (subject) is brown. Some Presidents (subject) in the world are brave in ruling (predicate).

2.3 Truth

The most important concept in science, mathematics and philosophy is the concept of truth. All that is captured

by the five senses of human beings about the world is considered as truth in science, mathematics and philosophy.

2.4 Statement

A sentence that is capable of being either true or false is defined as a statement. It is also called a declarative sentence. Any statement is either true or false, but not both [5].

2.4.1 General statement

A statement which claims that a predicate applies for every entity of a domain is defined as a general statement. For instance, all crows are black, all integers are real numbers and for every child has a mother. Any statement of the above form can be formally expressed as all Ps are Qs. Also, the statements mentioned above are not empirically valid because no one can observe all the Ps in the empirical world. This type of statement can be written more formally as $\forall x\big(P(x) \Rightarrow Q(x)\big)$.

2.4.2 Inductive generalization

If observing s number of entities that have a predicate F, n percent of F has a predicate G, then obtaining the conclusion that n percent of all F are G is called an inductive generalization. This statement is also not valid in the empirical world as in the case of general statement.

The general form of an inductive generalization can be written as follows.

"n percent of s thus-far-observed of F are G.

Therefore, about n percent of all F are G" [6].

We formally write the sentence that about n percent of all F are G as $\forall x\big(F_{n\%}(x) \Rightarrow G(x)\big)$.

2.4.3 Statistical generalization

If observing randomly (statistically) selected s number of entities that have a predicate F, n percent of F has a predicate G, then obtaining the conclusion that n percent of all F are G is called a statistical generalization.

This statement is also not valid in the empirical world as in the case of general statement. The general form of a statistical generalization can be written as follows.

"n percent of s randomly selected thus-far-observed of F are G.

Therefore, randomly (statistically) about n percent of all F are G" [6].

We formally write the sentence that about n percent of all F are G as $\forall x\big(F_{rn\%}(x) \Rightarrow G(x)\big)$.

2.4.4 Inductively Obtained Generalized Abstract Concepts and Statements

"If a general concept is created by the mental faculty through observing finite number of similar observations in the empirical world, then it is defined as an inductively obtained generalized abstract concept. If a general statement is created by the mental faculty through observing finite number of similar observations in the empirical world, then it is defined as an inductively obtained generalized abstract statement" [3]. These concepts and statements are not sensory perceptible.

2.5 Argument, premise and conclusion

An argument is a sequence of statements which are arranged in some order to acquire one statement as a conclusion [5]. The other statements, which are reinforced to arrive at the conclusion, are considered as premises of the argument. The premises provide the evidence to determine the conclusion

2.5.1 Deductive argument

A deductive argument is defined as follows: A deductive argument is an argument whose conclusion follows necessarily from its basic premise. More precisely, an argument is deductive if it is impossible for its conclusion to be false while its basic premises are all true [5]. We modify this statement as follows since truth is not defined in general way. A deductive argument is defined as follows: A deductive argument is an argument whose conclusion follows necessarily from its basic premise. More precisely, an argument is deductive if it is impossible for its conclusion to be not true while its basic premises are all assumed to be true.

2.5.2 Inductive argument

An inductive argument is defined as follows.

"An inductive argument is one whose conclusion is not necessarily relative to the premises; there is a certain probability that the conclusion is true if the premises are true, but there is also a probability that the conclusion is false even if the premises are true. The argument is said to be an inductive argument if both the premises and the conclusion of an argument are true of facts." [6]. We modify this statement as follows since truth is not defined in general way. An inductive argument is one whose conclusion is not necessarily relative to the premises; there is a certain probability that the conclusion is assumed to be true if the premises are assumed to be true, but there is also a probability that the conclusion is to be not true even if the premises are assumed to be true. If both the premises and the conclusion of an argument are assumed to be true of facts, then the argument is said to be a valid inductive argument.

2.6 Inference

Inference is defined as a process to obtain conclusions starting from a set of premises assuming to be true using Aristotelian logic [5].

2.6 Methods of reasoning

Reasoning is a mental process to obtain conclusions from a set of premises with respect to Aristotelian logic. Mathematicians, scientists, philosophers and logicians apply this reasoning process to derive conclusions in their fields of study [5]. In general, reasoning may be defined as a mental process to obtain conclusions with or without the help of five senses, starting from a set of premises with respect to a n-fold m-valued logic [7]. In the literature, there are three methods of reasoning that are used to arrive at conclusions in scientific experiments. The reasoning methods, namely inductive, abductive and deductive are described as follows.

2.6.1 Inductive reasoning

Forming a generalized abstract statement based on a finite number of similar observations in an experiment is called the inductive reasoning. For instance, suppose that we observe hundreds of non-crippled dogs from the universal set of non-crippled dogs as a sample. We can observe that the first dog has four legs, the second dog has four legs, the third dog has four legs and so on, and finally, the hundredth dog has also four legs. Therefore, it could be concluded that all the non-crippled dogs have four legs in the universal set of non-crippled dogs. On the other hand, the famous empiricist David Hume showed that generalized statements are not valid in the empirical world. We can write a generalized statement more formally as $\forall x\big(D(x) \Rightarrow F(x)\big)$, where $D(x)$ denotes that x is dog and $F(x)$ denotes that x has four legs. However, this statement that was obtained by the observations in the empirical world is not valid in that world because in this moment no one can observe the non-crippled dogs that would be born in future. Therefore, the scientific knowledge that is based on inductive reasoning is vulnerable.

2.6.2 Deductive reasoning

Based on a given generalized abstract statement, arriving at conclusions for a specific set of observations in an experiment is called deductive reasoning. According to rationalism before obtaining observations, the generalized abstract statement is created through the mental faculty. In empiricism, generalized statement is created only after obtaining observations. In deductive reasoning in empiricism the created generalized statement is justified from the finite number of empirical observations. David Hume showed that generalized statements cannot be verified in the empirical world. In our opinion, without any observation or imagination, no generalized statement can be created by the mind. There should be at least one observation or imagination to guess the generalized statement.

For instance,

If the body temperature of a person is greater than 98.4^0 F, then he or she has a fever. (Premise)

Nimal's body temperature is 100^0 F. (Premise)

Therefore, Nimal has a fever. (Conclusion)

In this argument, the sentence that if the temperature of the body of a person is greater than 98.4^0 F, then he or she has a fever, is the generalized abstract statement. This statement can be written formally as $\forall x\big(T(x) \Rightarrow F(x)\big)$, where $T(x)$ denotes that the temperature of x is greater than 98.4^0 F and $F(x)$ denotes that x has fever. If n denotes Nimal. Hence, we can formalize the above argument as follows;

$\forall x\big(T(x) \Rightarrow F(x)\big)$. (Premise)

$T(n)$. (Premise)

Therefore, $F(n)$. (Conclusion)

Further $\forall x\big(T(x) \Rightarrow F(x)\big)$ is only a conception and it is not valid in the empirical world as in the case of inductive reasoning. Therefore, the scientific knowledge that is based on deductive reasoning is also vulnerable.

2.6.3 Abductive reasoning

Forming creatively or intuitively or revolutionarily a plausible abstract explanation for an incomplete set of observations in an experiment or a set of experiments is called the abductive reasoning. There may be other explanations for the set of experiments. Abductive reasoning may be called creating a hypothesis that gives the best explanation to a set of observations. Abductive reasoning is essentially a process of guessing. For instance, one week ago, Saman told me that he had sold his car and wanted by a new one. Today, in the morning, I saw him driving a new car. Therefore, I presume that he has bought a new car.

Observation: Today in the morning, I saw Saman driving a new car.

Known fact: One week ago, Saman told me that he had sold his car and wanted buy a new one.

Hypothesis 1: I think that Saman has bought a new car.

Hypothesis 2: I think that Saman borrowed a car from a friend.

Hypothesis 3: I think that Saman hired a car.

Hypothesis 4: I think that Saman drove his wife's car. etc.

One can observe that there are many or perhaps infinite number of hypotheses. In this case, guessing the possible hypotheses and selecting the most possible one is an example for abductive reasoning. Within the known fact, there is a sentence that he wanted to buy a new one. According to this sentence, the most possible hypothesis is that he has bought a new car. In other words, I abducted that he has bought a new car. Since abductive reasoning is to obtain an explanation of the observations based on conclusions, this method of reasoning can be considered as a bottom-up process. In general, human being make decisions by abductive reasoning in their day today problems. In other words, abductive reasoning is in human nature. In this case,

abductive reasoning has been used for a particular case.

3. Difference between induction and abduction

Abduction in science is not confined to a single individual or a set of observations. Abduction in science is more general as in the case of induction, but it is not a generalization of the form made in induction. It is the art of arriving at a plausible explanation of a given set of observations. While induction is not an explanation, but a generalization, abduction is a general explanation for a set of observations.

4. Human nature and generalizations

Generally, human beings very much desire to keep all the information within their memory but it is impossible due to the lack of adequate memory in the case of human beings. Since human beings have weaknesses such as inadequate memory, forgetting the information stored in the memory and laziness etc. the people always try to keep information as small as possible in their memory. On the other hand, people are very eager to study the patterns and to obtain predictions in every phenomenon. Therefore, they construct generalizations as a strategy of reducing information. Hence, the generalization can be considered as a part of human nature.

5. Scientific experiments and reasoning

Generally, in most experiments of sociology and natural sciences the researchers arrive at conclusions based on the method of induction or deduction without considering the invalidity of these reasoning methods. To obtain a generalized statement, we need a set of similar observations. However, in empirical experiments, it is impossible to obtain a set of similar observations. To make a set of similar observations, the researchers may take actions to eliminate or modify the odd observations related to the experiments. On the other hand, there may be impossibilities to observe correct situations also. Normal procedure in collecting data in sociology is to obtain data by using questionnaires. When answering a questionnaire, people are not interested in providing correct information due to many reasons such as non-availability of time to spend, cultural issues, laziness and tendency to please the researcher etc. The researchers may design questionnaires to answer their thought questions that may not be real questions regarding the research area. The following specific examples given below explain how to obtain conclusions and theories by the abductive reasoning.

5.1 Police investigation

Sometime ago, an unknown gang of terrorists fixed a land mine on the up-country railway track in Sri Lanka. Fortunately, before the explosion, it was discovered by the police and immediately, they defused it. Further investigation by the police found only a plank of a bed and nothing else. After examining the plank, they guessed that there should be a co-relation between the land mine and the plank. To find the co-relation, the houses nearby where the land mine was placed were carefully checked by the police. In one house, they found a bed that did not have a plank and found that the plank discovered by the police fitted the bed. Having questioned the house owner, he accepted that the plank belonged to his bed and the plank was brought to place the land mine, as a defensive measure. At last, the police could trap the person who made this criminal case. In this

process, the police came to their conclusion step by step by using the method of abduction for a particular case not deduction or induction. If the police discovered a cap of a railway guard near the land mine, there may have to be another abductive process.

5.2 Diagnosing

In an experiment observing a patient suffering a disease, it is impossible to obtain all and correct information regarding the disease. Perhaps, the patient feels shy to tell the truth, he or she may be unconscious and he or she has cultural issues etc. Clearly, the doctor can get only an incomplete set of observations related to the patient. Based on that incomplete set of observations and using the past experiences, the doctor must guess the disease and act immediately to cure the patient. The conclusion may be somewhat creative and intuitive, and does not follow logically. The doctor could not obtain a set of similar observations and could not assume a general statement directly. Hence, in this process the inductive and deductive reasoning methods cannot be applied in this particular case. He guesses the most plausible disease using abductive reasoning. Briefly, we can say that the doctor abducts the disease. Sometimes, abduction could be wrong.

5.3 Discovering gravitation

Observing the behaviors of the planets in our solar system and falling apples, Isaac Newton hypothesized the theory of gravitation. According to his proposed theory all the planets in our solar system must move in fixed elliptic paths with the sun as a focus. However, it was known that the planet, Mercury moved in rotating elliptic paths. This observation does not follow from the theory of gravitation. At that time, Newton, creatively and revolutionarily provided the best explanation to the whole set of observations made by him on the motion of planets or falling objects. In other words, he abducted the theory of gravitation. However, the theory of gravitation did not explain the motion of the planets around the sun accurately.

5.4 Survey on school leavers

To analyze the situation of the school leavers in a country, the researchers must collect data from the society. There may be impossibilities in collecting correct data. Perhaps the people may not tell the truth, and give incorrect information involving school due to social effects. Also, the school leavers are not being in position to provide correct data, and hence give contradictory data. The researchers may use sampling techniques for statistical methods that are not an accurate in collecting data for the whole population. Analyzing the above data by using various types of statistical methods, researchers may come to conclusions as generalized statements that are not sensory perceptible at all. In this case, the researchers could try to obtain conclusions by using set of incomplete data as the best explanation. These methods of reasoning are neither inductive nor deductive. In this experiment, the conclusions have to be obtained through the method of abductive reasoning.

6. Conclusions

All the generalizations including inductive, and statistical inferences are only conceptions that are invalid within the empirical world in the sense described in 2.3. We consider that abductive reasoning is a part of human nature

and it is within normal thinking process of human beings. Analyzing the observations of scientific experiments, what the researchers perform is that they yarn a story to explain the observations as satisfying as possible.

7. Recommendations

Collecting the correct data is an important requirement in scientific research. We observed that the double-blind method is one of the best methods in collecting correct information. If the researcher disguises as a school leaver, then he could find correct information related to the school leavers. Also, if the research is about the beggars, the researchers should disguise as beggars to collect correct data, otherwise obtaining correct data regarding beggars could be very difficult. We explained that the logical invalidity of the inductive reasoning method and deductive reasoning method. Hence, we recommend that the scientific researchers should use the method of inductive reasoning and the method of deductive reasoning very carefully to obtain conclusions and observations in their experiments. Also, we emphasize that abductive reasoning should be used to construct new hypothesis as much as possible.

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